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Knowledge Management Performance Evaluation Based on Triangular Fuzzy Number

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Abstract

First, the paper briefly summarized the current situation and research tends of the knowledge management performance evaluation research. Then, we proposed a new method to determine weight and combined with indistinct integration evaluation method to evaluate enterprise knowledge management performance. Next, the new method's rationality and feasibility was proved by an example. Finally, the method's superiority when it is applied to the field of knowledge management performance evaluation was verified by comparing the results.

*Keywords:*Management, Performance Evaluation, Triangle Fuzzy Number, Indistinct Integration Evaluation Method;

1. Introduction

Knowledge Management is considered as the second revolution in global business management. Knowledge has become the key factor of improving the competitiveness of enterprises, economic growth and social development. Knowledge Management can improve business efficiency and competitiveness through systematic manage of knowledge resources, thus contributing to economic growth. The domestic and foreign scholars also recognize the importance of knowledge management, there are more and more scholars started to research in the field. Knowledge Management Performance Evaluation as an important part of knowledge management is also get more concern.

Knowledge management performance evaluation study include the design of Knowledge Management Performance Evaluation Criteria System and the select of the evaluation methods. Quitas [1] first proposed knowledge management performance evaluation criteria system, he considered the criteria system should include establish the strategy that help enterprise develop, access and share knowledge, knowledge strategy's implementation, through knowledge management to improve business performance and testing, evaluation, and knowledge-related management activities. Edvinsson and Sulliwan [2] (1996) established a knowledge management criteria including knowledge management course, enterprise knowledge structure, economic benefits and efficiency to measure the performance of knowledge management. Stewart [3] (1997) adopted the Balanced Scorecard established the criteria system contain the internal business operations, external customer-oriented learning, financial profit and non-financial business growth. Arthur Andersen[4] propose knowledge management Evaluation tools KMAT and raised through leadership, culture, assessment, technology and learning the five dimensions to assess the performance of knowledge management. YAN Guang-hua [5] (2001) divided the process of enterprise knowledge management into "short-term goal", "medium-term goal" and "long-term goal" three stages, and build index in the each stage, but the 3 phase are appear in turn and exist at the same time, so this indicator system lack rationality and feasibility. ZHENG Jing-li [6] (2003) refer to the research result of domestic and overseas scholars raised its index system, but there are so many indicators that it is difficult to measure. ZHOU Zhi-ying [7] (2009) adopt Balanced Scorecard to analyze enterprise knowledge management, set up a simple and practical knowledge management performance evaluation index system.

Another aspect of Knowledge management performance evaluation study is select of the knowledge management performance evaluation method, because of the knowledge management performance evaluation itself has some specialities, so the evaluation methods' selection needs to consider its own characteristics. Evaluation method that commonly used includes Fuzzy Evaluation

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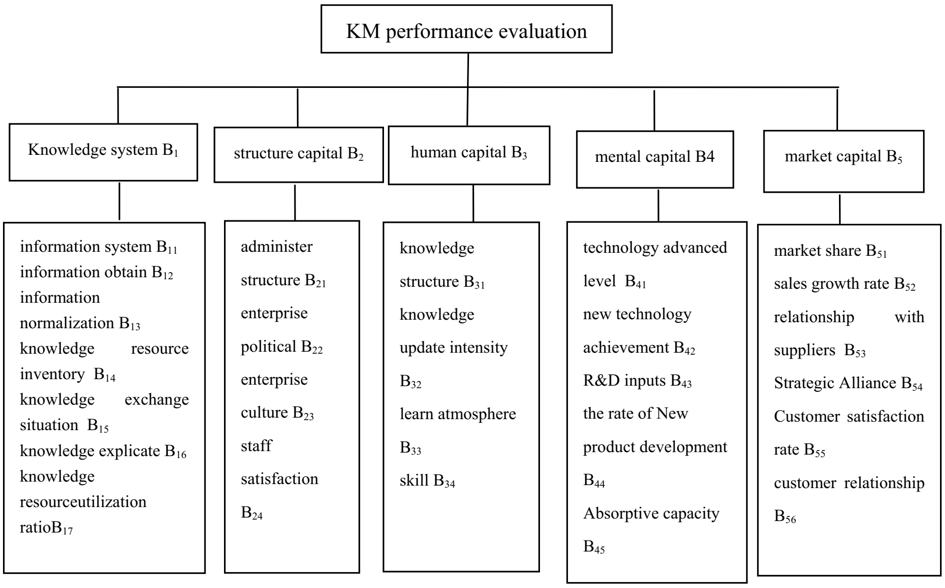
method [8], evidence reasoning combined Mass functions [9], AHP [10-11] and so on. Knowledge Management Performance Evaluation usually combined with the areas that include specific project [12], product development [13], information engineering supervision enterprises [14] and system dynamics [15] to study.

2. Knowledge Management Performance Evaluation System

To ensure the validity of evaluation results and reflect the problems and weak links during knowledge management implementation, the first step is establish a reasonable criteria system according to the company specific situation, and then select the appropriate evaluation method. Whether the designed index system is comprehensive and reasonable, directly influence the evaluation’s accuracy and effectiveness. If the target system lack of rationality, how can the evaluation results of reference value and guidance. We can see that the Index System's design is as important as the Method's Select, even more important than the choice of evaluation methods.

In this paper, Knowledge Management Performance Evaluation Criteria System as follows:



3. Evaluation Model of Enterprise Knowledge Management Performance

3.1. Weight Determination

3.1.1. Triangular Fuzzy Complementary Judgement Matrix

First, we used the evaluation scale in literature [16], as Table 1:

TABLE 1. EVALUATION SCALE AND ITS IMPLICATIONS

Comparing the importance	Scale（m_{ij}）
X_i and X_j are equally important	0.5
X_i important than X_j	>0.5
X_i isn't important than X_j	<0.5

Definition 1 Define Judgement Matrix $P = (p_{ij})_{n\times n}$, where $p_{ij} = (l_{ij}, m_{ij}, u_{ij})$, $p_{ji} = (l_{ji}, m_{ji}, u_{ji})$, if satisfied:

- $l_{ii} = m_{ii} = u_{ii} = 0.5, \forall i$；

- $l_{ij} + u_{ji} = 1, m_{ij} + m_{ji} = 1, u_{ij} + l_{ji} = 1, i \neq j, \forall i, j,$

Claimed that P is a triangular fuzzy number complementary matrix. Matrix's element p_{ij} signify the degree that X_i important than X_j.

Definition 2 the possibility of $M_1 \geq M_2$ is defined as:

$$V(M_1 \geq M_2) = \sup_{x \geq y}(\min(\mu_{M_1}(x), \mu_{M_2}(y)))$$

If $M_1 = (l_1, m_1, u_1)$, $M_2 = (l_2, m_2, l_2)$ *are two triangular fuzzy numbers, marking:*

$V(M_2 \geq M_1) = \mu(d)$, d is the intersection's horizontal of M_1 and M_2, there are:

$$V(M_2 \geq M_1) = \mu(d) = \begin{cases} \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}, l_1 \leq u_2 \\ 0, \quad others \end{cases} \tag{1}$$

3.1.2. The Basic Steps of weight determination

Suppose there are T decision-makers in decision-making, and every decision-makers given triangular fuzzy number to all indicators to constitute a triangular fuzzy number complementary judgement matrix (given all decision makers have equal status in decision-making), mark the triangular fuzzy numbers given by the NO.t decision-maker after compared the i-index and the j-index as $a_{ij}^t = (l_{ij}^t, m_{ij}^t, u_{ij}^t)$, while the NO.t expert compare a factor (criteria) of the k-1-level with the associated n_k factors of the k-layers, it will be following steps to determine weights:

(1)Construction of triangular fuzzy number complementary judgement matrix

The NO.t expert pairwise compare Factors (criteria) of K-1-level with the associated nk factors of the k-layers, according to definition 1 to give the triangular fuzzy number, get the Triangular Fuzzy Numbers Fuzzy Complementary Judgement

Matrix $A = (a_{ij}{}^t)_{n_k \times n_k}$, where $a_{ij}{}^t = (l_{ij}{}^t, m_{ij}{}^t, u_{ij}{}^t)$ is a closed interval that $m_{ij}{}^t$ is the median, $a_{ii}{}^t = (0.5, 0.5, 0.5)$ and

$l_{ij}{}^t + u_{ji}{}^t = 1, m_{ij}{}^t + m_{ij}{}^t = 1, u_{ij}{}^t + l_{ji}{}^t = 1, i \neq j, \forall i, j$

(2)Calculate the value of integrated degree $a_{ij}^t = (l_{ij}^t, m_{ij}^t, u_{ij}^t), i, j = 1, 2, \cdots, n_k, t = 1, 2, \cdots, T$, signify the triangular fuzzy number that given by the NO.t decision-makers compared NO.i factor with the NO.j factor of the k-level. According to the formula (1):

$$M_{ij}^k = \frac{1}{T} \otimes (a_{ij}^1 + a_{ij}^2 + \cdots + a_{ij}^T) \tag{2}$$

Obtain the integrated triangular fuzzy numbers of the k-layer, get the comprehensive judgement matrix of the k-layer to the NO.h element of the k-1-layer. According to the formula (3):

$$S_i^k = \sum_{j=1}^{n} M_{ij}^k \bullet (\sum_{i=1}^{n_k} \sum_{j=1}^{n_k} M_{ij}^k)^{-1}, i = 1, 2, \cdots n_k \tag{3}$$

Obtain the values of integrated fuzzy degree.

(3) Single-level sorting

According to the formula (1) calculation:

$$V(S_i^k \geq S_j^k), i, j = 1, 2, \cdots, n_k : i \neq j \tag{4}$$

$$P_{ih}^k(A_i^k) = \min V(S_i^k \geq S_j^k), i, j = 1, 2, \cdots, n_k : i \neq j \tag{5}$$

Represent the single-sort that every factor of the k-layers to the h factor of the k-1-layer. A_i^k represent the NO.i factors of the k-level. Normalization $P_{ih}^k(A_i^k)$ obtain:

$$P_h^k = (P_{1h}^k, P_{2h}^k, \cdots, P_{nh}^k)^T \tag{6}$$

Represent the single-sort that every factor of the k-layers to the h factor of the k-1-layer.

(4)Synthesis sorting

From the above P_h^k , when h = 1, 2, ... , n_{k-1}, we get $n_k \times n_k$ matrix:

$$P^k = (P_{1h}^k, P_{2h}^k, \cdots, P_{nh}^k)^T = \begin{bmatrix} P_{11}^k & P_{12}^k & \cdots & P_{1n_{k-1}}^k \\ P_{21}^k & P_{22}^k & \cdots & P_{2n_{k-1}}^k \\ \cdots & \cdots & \cdots & \cdots \\ P_{n_k1}^k & P_{n_k2}^k & \cdots & P_{n_kn_{k-1}}^k \end{bmatrix} \quad (7)$$

If the k-1-layer's ranking weight vector on the overall objective is:

$$W^{k-1} = (W_1^{k-1}, W_2^{k-1}, \cdots, W_{n_{k-1}}^{k-1})^T$$

then the k-layer's all elements' synthesis sorting W_k on the overall goal is given by the formula:

$$W^k = (W_1^k, W_2^k, \cdots, W_{n_k}^k)^T = P^k W^{k-1} \quad (8)$$

3.2. Fuzzy Evaluation

The main steps of indistinct integration evaluation method:

(1) Identify the factors set of evaluation objects U = (U_1, U_2 , ..., U_n), factors are the properties of evaluation object or the collection of index.

(2) Establish remark set V = (V_1, V_2 , ..., V_m).

(3) Statistics: Determine the membership vector of Single factor evaluation, and form the membership matrix R, where membership γ_{ij} represents the probability (probability level) that many evaluation subjects give V_j to an evaluation object of the U_i. Identify the R: U × V → [0, 1], γ_{ij} = R (U_i, V_j), formed the membership matrix R, R also known as single-factor evaluation matrix.

(4) Determine the weights of factors , because of the factors of U have different measurements, so factors are required to give different weights which can be expressed as a fuzzy subset of U , W = (w_1, w_2, ..., w_n), and provides:

$$\sum_{i=1}^{n} w_i = 1, \qquad w_i \geq 0, \qquad i = 1,2,\cdots \mathrm{n}$$

(5) Judgement comprehensive evaluation, after calculate U and W, the comprehensive evaluation is: B = WoR, remark B = (b_1, b_2 , ..., b_m) which is a fuzzy sets of V, where:

$$b_j = \mathop{\vee}_{\mathrm{i}=1}^{n} (w_i \wedge \gamma_{ij}) \qquad j = 1,2,\cdots m$$

B is a fuzzy subset, therefore it is the result of fuzzy evaluation. If $\sum_{j=1}^{m} b_j \neq 1$, it can be normalized, where the "o" can be understood as a compositional operations is constitute of any kind of fuzzy operator, and we choose Zadeh operator, which is denoted by M (∧, ∨) operator. Finally, we adopt the weighted average method to integrate B.

4. A case study

The data this paper used was quote from the article [17], and requested three experts to transform the integer of the comparison matrix of article [17] into rational triangular fuzzy number. According to the above steps to program by Matlab to calculate the weight, as follows:

① The weights of the first level's index

TABLE 2. WEIGHTS OF THE FIRST LEVEL INDEX

B1	B2	B3	B4	B5
0.3542	0.2727	0.212	0.1217	0.0395

②For knowledge systems

TABLE 3. WEIGHTS OF THE SECONDARY INDEX OF THE KNOWLEDGE SYSTEMS

B11	B12	B13	B14	B15	B16	B17
0.2555	0.1752	0.1068	0.0572	0.0814	0.1216	0.2023

③ For structure of capital

TABLE 4. WEIGHTS OF THE SECONDARY INDICATORS OF CAPITAL STRUCTURE

B21	B22	B23	B24
0.2937	0.4407	0.2168	0.0488

④For human capital

TABLE 5. WEIGHTS OF THE SECONDARY INDICATORS OF HUMAN CAPITAL

B31	B32	B33	B34
0.2485	0.3493	0.1018	0.3003

⑤ For mental capital

TABLE 6. WEIGHTS OF THE SECONDARY INDICATORS OF TECHNOLOGY CAPITAL

B41	B42	B43	B44	B45
0.2337	0.2964	0.2172	0.1376	0.1151

⑥ For market capital

TABLE 7. WEIGHTS OF THE SECONDARY INDICATORS OF MARKET CAPITALIZATION

B51	B52	B53	B54	B55	B56
0.2368	0.1974	0.0664	0.1259	0.1660	0.2075

After calculating the weights, compare with the weights obtained by AHP in the literature [17], we can see they are very close, so the weight determination method is reasonable and feasible. The existence of small bias due to the triangular fuzzy numbers take the fuzzy nature of human subjective consciousness into account, it is more objective and reasonable than directly represent the people's preference by a specific integer.

The rating degree is divided into five, namely V = (very good, good, fair, poor, very poor), which was assigned (1, 2, 3, 4, 5).

According to V invite 10 experts to rate the secondary indicators and sorted out, obtained the following table:

TABLE 8. SAMPLE DATA

Index	Ratio of rating degree				
	V_1	V_2	V_3	V_4	V_5
B_{11}	0	0.5	0.4	0.1	0
B_{12}	0	0.5	0.4	0.1	0
B_{13}	0	0.5	0.3	0.2	0
B_{14}	0	0.4	0.5	0.1	0
B_{15}	0	0.5	0.4	0.1	0
B_{16}	0	0.5	0.4	0.1	0
B_{17}	0.1	0.5	0.4	0	0
B_{21}	0	0.5	0.4	0.1	0
B_{22}	0.1	0.5	0.4	0	0
B_{23}	0	0.4	0.5	0.1	0
B_{24}	0	0.5	0.4	0.1	0
B_{31}	0	0.6	0.4	0	0
B_{32}	0	0.4	0.5	0.1	0
B_{33}	0	0.5	0.4	0.1	0
B_{34}	0	0.4	0.4	0.2	0
B_{41}	0	0.5	0.4	0.1	0
B_{42}	0.1	0.7	0.2	0	0
B_{43}	0.2	0.8	0	0	0
B_{44}	0.1	0.7	0.2	0	0
B_{45}	0	0.7	0.7	0	0
B_{51}	0	0.6	0.3	0.1	0
B_{52}	0.1	0.8	0.1	0	0
B_{53}	0.1	0.8	0.1	0	0
B_{54}	0	0.4	0.4	0.2	0
B_{55}	0	0.4	0.4	0.2	0
B_{56}	0	0.5	0.4	0.1	0

(1)From previously calculated available:

W=（0.3542，0.2727， 0.212，0.1217，0.0395）

W_1=(0.2555，0.1752，0.1068，0.0572，0.0814，0.1216，0.2023)

W_2=(0.2937，0.4407，0.2168，0.0488)

W_3=(0.2485，0.3493，0.1018，0.3003)

W_4=(0.2337，0.2964 ，0.2172，0.1376，0.1151)

W_5=(0.2368，0.1974，0.0664，0.1259，0.166，0.2075)

(2)Evaluation matrix

$$R_1 = \begin{bmatrix} 0 & 0.5 & 0.4 & 0.1 & 0 \\ 0 & 0.5 & 0.4 & 0.1 & 0 \\ 0 & 0.5 & 0.3 & 0.2 & 0 \\ 0 & 0.4 & 0.5 & 0.1 & 0 \\ 0 & 0.5 & 0.4 & 0.1 & 0 \\ 0 & 0.5 & 0.4 & 0.1 & 0 \\ 0.1 & 0.5 & 0.4 & 0 & 0 \end{bmatrix}$$

$$R_2 = \begin{bmatrix} 0 & 0.5 & 0.4 & 0.1 & 0 \\ 0.1 & 0.5 & 0.4 & 0 & 0 \\ 0 & 0.4 & 0.5 & 0.1 & 0 \\ 0 & 0.5 & 0.4 & 0.1 & 0 \end{bmatrix}$$

$$R_3 = \begin{bmatrix} 0 & 0.6 & 0.4 & 0 & 0 \\ 0 & 0.4 & 0.5 & 0.1 & 0 \\ 0 & 0.5 & 0.4 & 0.1 & 0 \\ 0 & 0.4 & 0.4 & 0.2 & 0 \end{bmatrix}$$

$$R_4 = \begin{bmatrix} 0 & 0.5 & 0.4 & 0.1 & 0 \\ 0.1 & 0.7 & 0.2 & 0 & 0 \\ 0.2 & 0.8 & 0 & 0 & 0 \\ 0.1 & 0.7 & 0.2 & 0 & 0 \\ 0 & 0.7 & 0.7 & 0 & 0 \end{bmatrix}$$

$$R_5 = \begin{bmatrix} 0 & 0.6 & 0.3 & 0.1 & 0 \\ 0.1 & 0.8 & 0.1 & 0 & 0 \\ 0.1 & 0.8 & 0.1 & 0 & 0 \\ 0 & 0.4 & 0.4 & 0.2 & 0 \\ 0 & 0.4 & 0.4 & 0.2 & 0 \\ 0 & 0.5 & 0.4 & 0.1 & 0 \end{bmatrix}$$

(3) Synthesize Evaluation

$$B_1^{'} = W_1 R_1 = (0.0202, 0.4943, 0.3950, 0.0905, 0)$$
$$B_2^{'} = W_2 R_2 = (0.0441, 0.4783, 0.4217, 0.0559, 0)$$
$$B_3^{'} = W_3 R_3 = (0, 0.4599, 0.4349, 0.1052, 0)$$
$$B_4^{'} = W_4 R_4 = (0.0868, 0.6750, 0.2148, 0.0234, 0)$$
$$B_5^{'} = W_5 R_5 = (0.0264, 0.5736, 0.2972, 0.1028, 0)$$

After normalization, available:

$$B_1 = (0.0202, 0.4943, 0.3950, 0.0905, 0)$$
$$B_2 = (0.0441, 0.4783, 0.4217, 0.0559, 0)$$
$$B_3 = (0, 0.4599, 0.4349, 0.1052, 0)$$
$$B_4 = (0.0868, 0.6750, 0.2148, 0.0234, 0)$$
$$B_5 = (0.0264, 0.5736, 0.2972, 0.1028, 0)$$

Get R = (B1, B2, B3, B4, B5) T, where

$$R = \begin{bmatrix} 0.0202, 0.4943, 0.3950, 0.0905, 0 \\ 0.0441, 0.4783, 0.4217, 0.0559, 0 \\ 0, \quad 0.4599, 0.4349, 0.1052, 0 \\ 0.0868, 0.6750, 0.2148, 0.0234, 0 \\ 0.0264, 0.5736, 0.2972, 0.1028, 0 \end{bmatrix}$$

Available: $B = WR = (0.0308, 0.5078, 0.3850, 0.0765, 0)$

$$B \circ V^T = [0.0308, 0.5078, 0.3850, 0.0765, 0] \begin{pmatrix} 2 \\ 1 \\ 0 \\ -1 \\ -2 \end{pmatrix} = 0.4929$$

The enterprise knowledge management performance evaluation result is 0.4929, between 0 and 1. The enterprise knowledge management performance is between general and good, agree with the result of literature [17], indicating that the method is of rationality and feasibility.

5. Conclusions

The Knowledge Management Performance Evaluation Methods we proposed for determining the weight compared with Triangular Fuzzy AHP is more operational and practical. Compared with the AHP it takes the ambiguity of people's subjective consciousness into account so that it is more rationale. And it is simpler than Triangular Fuzzy AHP. The method improved the existing triangular fuzzy AHP method to some extent and make it more feasible.

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